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H4.SMR/537-27

SECOND COLLEGE ON THEORETICAL AND EXPERIMENTAL RADIOPROPAGATION PHYSICS
(7 January - 1 February 1991)

Co-sponsered by ICTP, URSI, ICSU and with the participation of ICS

COMPUTER PROGRAMS FOR IONOSPHERIC RADIOWAVE PROPAGATION

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Programs WOMAP and HRMNTH

CCIR Report 340 (Atlas of ionospheric characteristics) contains reference data defining monthly median values of the standard ionospheric characteristics scaled from a vertical-incidence ionogram. Orthogonal Fourier polynomials and associated numerical coefficients are used to represent the geographical and universal time variations. There are separate sets of coefficients for each month for reference low and high solar epochs (corresponding to smoothed sunspot number R_{12} = 0 and 100 respectively). Linear interpolation/extrapolation to any other sunspot number appropriate to a particular year is assumed. The number of coefficients varies with the ionospheric characteristic being mapped.

Using also reference information on the decile deviations about the monthly median taken from other CCIR reports and coefficients contained on floppy disk, programs WOMAP and HRMNTH for PC evaluation give respectively a printout on a full or part world map grid for a specified month and UT hour and a printout for a specified location at a series of months and hours any of the following:

monthly median, upper and lower decile foF2

monthly median M(3000)F2, h'F, h'F-F2, foE and foF1

monthly median, upper and lower decile foEs

Figures 1 and 2 show WOMAP and HRMNTH examples respectively.

Operating instructions

General

Programs can be run using the disks supplied or via a hard-disk drive. Type 'WOMAP' or 'HRMNTH' as appropriate for a system with maths co-processor or 'WOMAPX' and 'HRMNTHX' if there is no co-processor. User-interactive questions relating to the configuration are then asked.

Disk 1 contains the version of the program for use with a maths co-processor, together with an example input data file. Disk 2 holds the executable binary code for the non-coprocessor version and the source code (usable with both versions).

Typing 'CON' directs output to a console and 'PRN' to an on-line printer. Input files, formatted as indicated below, and requested by the program, can be created using the MS-DOS 'EDLIN' command or by means of a proprietary editor.

WOMAP input

line 1 Number of latitudes (maximum 37) and longitudes (maximum 12) defining the grid points for which calculations are to be made. (Format I5. Number of latitudes columns 1-5; number of longitudes columns 6-10).

lines 2 etc Latitudes, degrees and decimal degrees with N positive. (Format F10.2, maximum 8 to a line, columns 1-10 etc).

Next lines Longitudes degrees and decimal degrees E positive or W negative of Greenwich. (Format F10.2, maximum 8 to a line, columns 1-10 etc).

Next line Times of start, finish and step of calculations in integer hours UT. (Format I5, columns 1-5 etc).

Next line Month number (Format I5, columns 1-5); year (Format A4, columns 7-10); 12-months running mean sunspot number R12 (Format F10.1, columns 11-20) and 10.7 cm solar noise flux number (Format F 10.1, columns 21-30).

(Note Calculations work in terms of sunspot number unless R12 is set negative)

Last line Ionospheric characteristic code number KK (Format I5, columns 1-5); program control index KOUNT (Format I5, columns 6-10).

(Note KK=1 for foF2 monthly median; KK=2 for a combined printout of the foF2 monthly median, lower and upper deciles; KK=3, 5, and 6 give monthly median M(3000)F2, h'F and h'F-F2 respectively; 7, 9, 11 produce foEs monthly median, lower decile and upper decile respectively; 15, 17, yield monthly median foE and foF1 respectively).

Successive batches of calculations can be performed using KOUNT as follows: 0 and 4 (halts following batch), 1 (new set of latitudes and longitudes), 2 (new year and solar epoch), 3 (new ionospheric characteristic).

HRMNTH

line 1 Name of location (up to 20 characters) for which calculations are wanted SITE (Format 5A4, columns 1-20); latitude (Format F10.1, columns 21-30); longitude (Format F10.1, columns 31-40).

lines 2 and 3 (both always present) Number of times up to 24 (Format I3, columns 1-3); times UT with 12 to a line in hours and decimal hours, TIME (Format F6.2, columns 4-9 etc).

line 4 Year IYEAR (Format A4, columns 2-5); type of solar-activity index for interpolation IS (Format I5, columns 6-10).

(Note IS = 0 for smoothed sunspot number; 1 for solar flux)

line 5 Twelve values of solar activity index for January-December of IYEAR (Format F6.1, columns 4-9, 10-15 etc).

line 6 Ionospheric characteristics code number and program control index - same as last line of WOMAP input, but with KOUNT = 1 for new SITE and TIME; KOUNT = 2 for new IYEAR and IS.

PAB/MID
January 1991

PROGRAM 'MICRO-MONAP' VERSION OCT 90

MEDIAN FOF2 USING CCIR COEFFICIENTS(OBLQ) DEC SUNSPOT NO.100.0 CCIR DATA SET B

1200 U.T.

LMT	12	14	16	18	20	22	0	2	4	6	8	10
LONG	0	30	60	90	120	150	180	210	240	270	300	330
LAT												
90	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31	5.31
85	4.02	3.93	3.93	4.08	4.41	4.84	5.21	5.36	5.23	4.88	4.49	4.20
80	4.34	4.27	3.95	3.69	3.77	4.19	4.69	4.96	4.85	4.42	4.14	4.19
75	5.49	5.49	4.72	3.75	3.32	3.51	4.01	4.36	4.31	3.97	4.07	4.80
70	6.91	6.99	5.77	4.07	3.04	2.94	3.37	3.78	3.76	3.54	4.18	5.60
65	8.25	8.38	6.84	4.52	2.92	2.55	2.91	3.36	3.32	3.20	4.42	6.61
60	9.30	9.43	7.73	5.02	2.98	2.38	2.69	3.13	3.02	2.98	4.77	7.47
55	9.96	10.03	8.34	5.49	3.19	2.45	2.60	3.08	2.90	2.92	5.21	8.21
50	10.22	10.14	8.63	5.92	3.56	2.71	2.82	3.15	2.92	3.01	5.74	8.79
45	10.15	9.86	8.63	6.28	4.09	3.18	3.07	3.28	3.06	3.25	6.34	9.22
40	9.94	9.45	8.52	6.70	4.82	3.89	3.44	3.40	3.23	3.58	6.99	9.55
35	9.98	9.46	8.68	7.44	5.89	5.02	4.02	3.52	3.36	3.95	7.66	9.86
30	10.75	10.58	9.65	8.96	7.53	6.76	4.97	3.68	3.40	4.28	8.32	10.25
25	12.33	12.80	11.79	11.35	9.80	9.05	6.46	4.03	3.35	4.58	8.93	10.87
20	13.53	14.01	14.00	12.91	11.59	10.75	8.39	4.77	3.36	4.57	9.48	11.77
15	12.44	12.01	13.57	11.31	10.81	10.09	9.82	6.00	3.70	4.60	9.98	12.68
10	10.28	10.10	11.13	9.58	8.82	8.30	9.25	7.08	4.58	4.82	10.50	12.85
5	10.19	10.69	10.55	9.86	8.83	8.32	7.72	6.71	5.15	5.49	11.10	11.74
0	11.10	11.31	11.10	10.73	9.61	9.04	7.96	5.70	5.00	6.25	11.67	10.30
-5	11.40	11.38	11.65	11.64	10.72	9.80	8.76	6.37	5.17	6.41	11.66	9.80
-10	11.43	11.15	11.76	11.56	11.34	10.54	9.18	7.29	6.12	6.45	10.87	9.86
-15	11.35	10.65	11.24	10.57	10.77	10.59	9.58	7.30	6.49	6.59	10.01	9.87
-20	11.18	10.03	10.37	9.30	9.46	9.93	9.60	7.62	6.50	6.48	9.42	9.99
-25	10.72	9.40	9.49	8.15	8.06	8.97	9.17	7.57	6.61	6.57	8.96	10.24
-30	10.28	8.87	8.73	7.26	6.93	8.04	8.52	7.25	6.65	7.01	8.88	10.46
-35	9.84	8.46	8.13	6.64	6.17	7.29	7.84	6.79	6.52	7.48	9.16	10.54
-40	9.43	8.13	7.64	6.22	5.73	6.73	7.21	6.31	6.28	7.78	9.51	10.46
-45	9.04	7.85	7.21	5.96	5.54	6.33	6.66	5.88	6.01	7.79	9.66	10.22
-50	8.62	7.54	6.82	5.81	5.51	6.03	6.17	5.51	5.76	7.61	9.50	9.80
-55	8.13	7.16	6.46	5.73	5.35	5.79	5.73	5.20	5.54	7.27	9.01	9.19
-60	7.53	6.72	6.13	5.70	5.61	5.57	5.34	4.95	5.35	6.84	8.27	8.41
-65	6.89	6.27	5.89	5.71	5.62	5.34	5.00	4.76	5.19	6.38	7.44	7.53
-70	6.33	5.94	5.78	5.73	5.58	5.14	4.74	4.59	5.04	5.96	6.68	6.74
-75	5.99	5.82	5.77	5.72	5.48	4.99	4.58	4.51	4.92	5.61	6.12	6.20
-80	5.89	5.83	5.78	5.63	5.31	4.87	4.53	4.50	4.83	5.35	5.76	5.91
-85	5.71	5.69	5.58	5.37	5.08	4.78	4.38	4.57	4.78	5.10	5.42	5.62
-90	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77	4.77

Fig 1

PROGRAM 'MICRO-MMNTH' VERSION OCT 89

MEDIAN FOF2 USING CCIR COEFFICIENTS(OBLQ) CCIR DISK SET B

LATITUDE 51.5 LONGITUDE 359.4 SLOUGH,UK 1988

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
UT	55.0	59.0	63.0	69.0	75.0	81.0	88.0	94.0	101.0	108.0	114.0	120.0	SUNSP
1.00	2.79	3.09	3.62	4.20	4.84	5.10	5.31	4.70	4.54	4.46	3.61	3.48	
2.00	2.80	3.14	3.58	3.92	4.49	4.81	4.90	4.30	4.28	4.40	3.74	3.61	
3.00	2.77	3.05	3.34	3.63	4.34	4.72	4.59	4.02	3.88	3.99	3.60	3.66	
4.00	2.47	2.59	2.99	3.57	4.47	4.87	4.61	4.06	3.65	3.39	3.05	3.28	
5.00	2.02	2.22	2.99	3.88	4.81	5.17	4.92	4.49	3.94	3.38	2.69	2.68	
6.00	2.07	2.46	3.65	4.46	5.23	5.51	5.30	5.17	4.75	4.48	3.39	2.80	
7.00	3.11	3.95	4.74	5.09	5.73	5.86	5.65	5.85	5.69	6.25	5.24	4.30	
8.00	4.72	5.35	5.76	5.71	6.21	6.15	5.99	6.36	6.48	7.88	7.42	6.68	
9.00	6.05	6.32	6.51	6.29	6.52	6.31	6.30	6.65	7.08	9.04	9.15	8.81	
10.00	6.78	6.94	7.08	6.73	6.61	6.33	6.46	6.76	7.53	9.87	10.28	10.13	
11.00	7.18	7.41	7.51	6.98	6.65	6.28	6.46	6.75	7.81	10.44	11.00	10.84	
12.00	7.47	7.64	7.71	7.07	6.74	6.25	6.41	6.71	7.89	10.68	11.35	11.25	
13.00	7.52	7.63	7.71	7.12	6.81	6.22	6.37	6.67	7.87	10.69	11.37	11.38	
14.00	7.25	7.55	7.65	7.12	6.77	6.15	6.29	6.60	7.78	10.65	11.11	11.10	
15.00	6.75	7.44	7.59	7.08	6.66	6.06	6.15	6.50	7.70	10.49	10.54	10.37	
16.00	6.02	7.05	7.49	7.07	6.62	6.01	6.08	6.48	7.68	10.03	9.50	9.19	
17.00	5.07	6.32	7.24	7.13	6.70	6.08	6.19	6.68	7.71	9.20	8.01	7.68	
18.00	4.08	5.46	6.78	7.12	6.86	6.29	6.46	7.05	7.60	8.07	6.40	6.19	
19.00	3.36	4.65	6.08	6.83	6.94	6.51	6.70	7.25	7.15	6.81	5.05	5.01	
20.00	2.96	3.91	5.28	6.25	6.80	6.58	6.72	7.04	6.44	5.69	4.15	4.19	
21.00	2.75	3.35	4.61	5.57	6.39	6.42	6.47	6.50	5.72	5.00	3.71	3.70	
22.00	2.69	3.13	4.16	4.99	5.89	6.10	6.10	5.90	5.19	4.73	3.59	3.49	
23.00	2.74	3.13	3.87	4.61	5.49	5.76	5.81	5.44	4.85	4.60	3.58	3.46	
24.00	2.79	3.11	3.68	4.39	5.18	5.44	5.60	5.07	4.67	4.48	3.55	3.46	

Fig 2

PROGRAM MUFFY
(Microcomputer-version)

Introduction

Recommendation 373 defines the basic MUF as the highest frequency at which a radio wave can propagate between given terminals on a specified occasion by ionospheric refraction alone. In principle, evaluation of the basic MUF requires a knowledge of the ionisation over the path where the path itself is determined by that same ionisation. In practise, however, approximate procedures are usually adequate. Report 340 gives reference ionospheric data and simplified algorithms which can be used to estimate the basic MUF. In particular, great-circle propagation is assumed with an ionosphere appropriate to midpath conditions for path length up to 4000 km and the so-called 'two-control point' approach for longer paths.

Program MUFFY, outlined in Part 12 of Report 340, is a computer procedure giving the basic MUF for either the short or long great-circle path. It has been prepared in response to Resolution 63 which requests the Director CCIR to make available computer programs in standardised language for the prediction methods described in Study Group 6 Reports and Recommendations. MUFFY is available in mainframe and microcomputer versions. A description of the mainframe version has been presented by Dick et al (1985). This microcomputer version description reproduces appropriate material from that earlier draft.

MUFFY, version JULY 90, has been written in FORTRAN 77 language for implementation on an IBM PC or compatible microcomputer having about 380 kbyte of available core storage, and a disk drive. It permits the calculation of the basic MUF at integer hours UT over a fixed path between specified terminals in a given month and for a quoted level of solar activity (Figs 3-6 provide sample output results). Also evaluated is an approximation of the optimum traffic frequency (FOT). The FOT is defined in Recommendation 373 as the lower decile of the daily values of operational MUF at a given time, where the operational MUF is the highest frequency that would permit acceptable operation of a specified radio service at a given time. Here the FOT is calculated in terms of the corresponding operational MUF.

The reference data given in Report 340 for the F2 layer are of two alternate types, known respectively as the Oslo and New Delhi coefficients. Program MUFFY accesses CCIR Data Disk Set B (Resolution 63) and can use either of these.

Section 2 provides a technical description of the procedure followed and the remaining sections of this handbook discuss program input and output arrangements.

Technical description of the procedure

General approach

The procedure for estimating the path basic MUF and the path operational MUF consists of the following separate stages:

(i) determination of the great-circle path and path length.

(ii) depending on the path length, identification of a number of propagation modes involving reflection from the E, F1 and F2 layers.

(iii) evaluation separately of the basic MUF for each of these modes. This is given as the product of the corresponding layer critical frequency at a defined location and the MUF factor for that mode. The MUF factor is an empirical function of hop length.

(iv) the path basic MUF is taken as the greatest of the MUF's for the separate modes.

(v) the path operational MUF is taken as the greatest of the E,F1 and F2 modes operational MUF's.

(vi) evaluation separately of the FOT for each mode as a given fraction of the corresponding operational MUF for the mode.

(vii) the FOT for the path is taken as the greatest of the FOT's for the separate modes.

Note that on occasions the path FOT may relate to a different mode than the path basic MUF.

Propagation modes, lengths and ionospheric positions sampled

The following table indicates for the E, F1 and F2 modes with a transmitter-receiver separation D, the hop distance d used for the evaluation of MUF factor M(d) and the position x from the transmitter at which the ionosphere is sampled. In the two control point procedure for F2 modes with D > 4000 km the MUF is taken as the lower of the two values at points 2000 km from each terminal.

MODE	D (km)	d (km)	x (km)
	0-2000	D	$\frac{D}{2}$
E	2000-4000	2000	$\frac{D}{2}$
	>4000	-	-
F1	2000-3400	D	$\frac{D}{2}$
	0-4000	D	$\frac{D}{2}$
F2	>4000	4000	2000 and D-2000

Critical frequencies

foE is given by equations 1-7 of Section 2.1 of Part 4 of Report 340; the foF1 is given by the equations of Section 2 of Part 5. In the case of foF2 there are two versions. The equations on which the Oslo coefficients are based are presented in Part 2, Sections 2 and 3.1. The Oslo coefficients involve a separate mapping of foF2 as a function of geographical latitude, longitude and Universal Time for each month of the year and two reference levels of smoothed sunspot number, R_{12}=0 and 100. Linear interpolation or extrapolation for any general R_{12} up to a limiting value of R_{12}=150 is assumed.

The New Delhi coefficients apply for a single representation of foF2 as a function of geographical latitude, longitude, Universal Time, day number (in the range 1-365) and smoothed sunspot number. The solar-cycle dependence is second degree. The equations used, which are a development from those employed with the Oslo coefficients, are presented by Jones and Obitts (1970). The New Delhi coefficients are recommended for use in short-term prediction programs (Section 3.2 of Part 2 of Report 340) but normally the Oslo coefficients should be used when determining the basic MUF.

MUF factors

The E mode MUF factor is given by the equations of Section 2.2 of Part 4 of Report 340. The F1 mode MUF factor is given by the equations of Section 3 of Part 5. For the F2 mode it is the first necessary to evaluate

$$F2(ZERO)MUF = foF2 + f_H/2$$

where f_H is the electron gyrofrequency

and

$$F2(4000)MUF = 1.1 \times foF2 \times M(3000)F2$$

where M(3000)F2 is mapped as a function of geographical latitude, longitude and Universal Time in a similar way to the mapping of foF2. The basic MUF for distance D is then given in terms of F2(ZERO)MUF and F2(4000)MUF using equations developed by Lockwood (1983) and described in Section 5 of Part 2 of Report 340.

Operational MUF

For F2-modes the operational MUF is the product of the basic MUF and the factor R_{op} as given from Table II of Part 3 of Report 340. For E and F1 modes the operational MUF is equal to the basic MUF.

The path operational MUF is the greatest of the operational MUF's for E, F1 and F2 modes.

The FOT

For F2 modes the FOT is taken as 0.85 times the operational MUF. For E and F1 modes the FOT is equal to 0.95 times the respective basic MUF's. The path FOT is the greatest of the FOT's for E, F1 and F2-modes.

Input data

Parameters required to specify a circuit

Input data requirements are as indicated below. Units in which quantities are expressed are as shown on the display.

Circuit/operational parameters

(i) Selection of Oslo or New Delhi foF2 coefficients.

(ii) Computation for the short or long great-circle path.

(iii) Latitude and longitude of the transmitter and receiver.

(iv) Month, smoothed sunspot number and calendar year.

(v) Universal Times.

System parameter

Transmitter power.

Cursor-interactive input

This input system is written in Turbo Pascal 4 as this language provides facilities which are not available with standard Fortran 77. It is an adaptation of that used in the microcomputer version of the method of Report 894 (Dick and Sizun, 1990).

Three displays are provided:

(i) An input file display listing the circuit data sub-sets of those circuits held in the directory. (Figure 1).

(ii) An edit display which lists all the parameters of a given circuit data set. (Figure 2).

(iii) A multiple run display which can be composed in order to perform successive calculations for particular circuit combinations. (This can also be used for a single circuit).

A selection of operations as described below is available with these displays.

On loading MUFFY a Turbo Pascal 4 program (INPMUF.EXE) is called and the input file is viewed.

Calculations can be performed in input file display mode, multiple circuit run mode or edit display mode.

Input file display mode

With the cursor keys an individual circuit can be highlighted and then using the function keys F1-F8 various operations performed on it.

Cursor highlighting actions are as follows:

Up arrow: moves cursor upwards one circuit in list

Down arrow: moves cursor downwards one circuit

Page up: moves cursor to first circuit on next page

Page down: moves cursor to first circuit on previous page

Home: moves cursor to first circuit in directory

End: moves cursor to last circuit in directory

Pressing the RETURN key also moves the cursor downwards one entry.

The designation of the function keys for individual circuit operation is:

- F1. Performs calculations and send output to printer
- F2. Performs calculations and sends output to the VDU
- F3. Performs calculations and sends output to a disk file
- F4. Enters edit display and run mode
- F5. Enters multiple circuit assembly and run mode
- F6. Deletes the circuit data set from the directory
- F7. Renumbers circuit data sets
- F8. Quits program

Multiple-circuit assembly and run mode

This facility, which is entered by pressing key F5, provides batch running of up to 50 circuits at a time. Batches are assembled and run. For assembly, circuits included in the directory are reviewed by placing the cursor over the circuit name using the arrow keys. A particular circuit is selected by pressing key F4 (in which case a highlighted number appears next to the circuit name and the cursor moves automatically to the next circuit of the directory). the running total number of circuits selected appears in the top right-hand corner of the screen.

The designation of the function keys for multiple circuit section and running is:

- F1. Runs multiple circuits and sends output to printer
- F2. Runs multiple circuits and sends output to VDU
- F3. Runs multiple circuits and sends output to a disk file
- F4. Selects a circuit for a multiple run
- F5. Quits multiple run selection facility

Edit display and run mode

After pressing the F4 key whilst in the input file display a new screen display appears giving in the top half a listing of parameters for the previously highlighted circuit. The cursor appears highlighting the first parameter (the Method).

Parameters are reviewed by using the arrow key commands:

These are as follows:

Up arrow: moves upwards one parameter
Down arrow: moves downwards one parameter
Left arrow: moves back one parameter in list
Right arrow: moves onto next parameter in list
Also the RETURN key moves onto next parameter in list.

Every time the cursor is moved a corresponding message is displayed towards the bottom half of the screen, explaining what the parameter is and advising the user regarding the limits imposed and units to be used. To change a parameter just move the cursor over it and type in the new value, followed by a 'RETURN'. A small message appears mid-screen to advise of invalid entries, in which case enter again until the value is valid.

The backspace key can be used to delete a character.

An example of edit display formats is shown in Figure 2.

In the edit display and run mode the function keys are employed as follows:

- F1. Performs calculations for viewed circuit and sends output to printer
- F2. Performs calculations for viewed circuit and sends output to VDU
- F3. Performs calculations for viewed circuit and sends output to a disk file
- F4. Stores edited circuit data set in input file directory
- F5. Quits edit mode and returns to input file display mode

Transmitter and receiver coordinate representations

The compass pointing (N, E, S, W) may be immediately before or after the numerical coordinates or, following IFRB practise, between the integer and fractional parts. Examples of these three forms are N51.56,51.56N and 51N56 respectively. The quantities N52 and 52N are interpreted as 52 degrees north. These options are additional to the ability to input coordinates either in decimal degrees or degrees and minutes.

Output

Output examples showing the formats provided are given in Figures 3-6.

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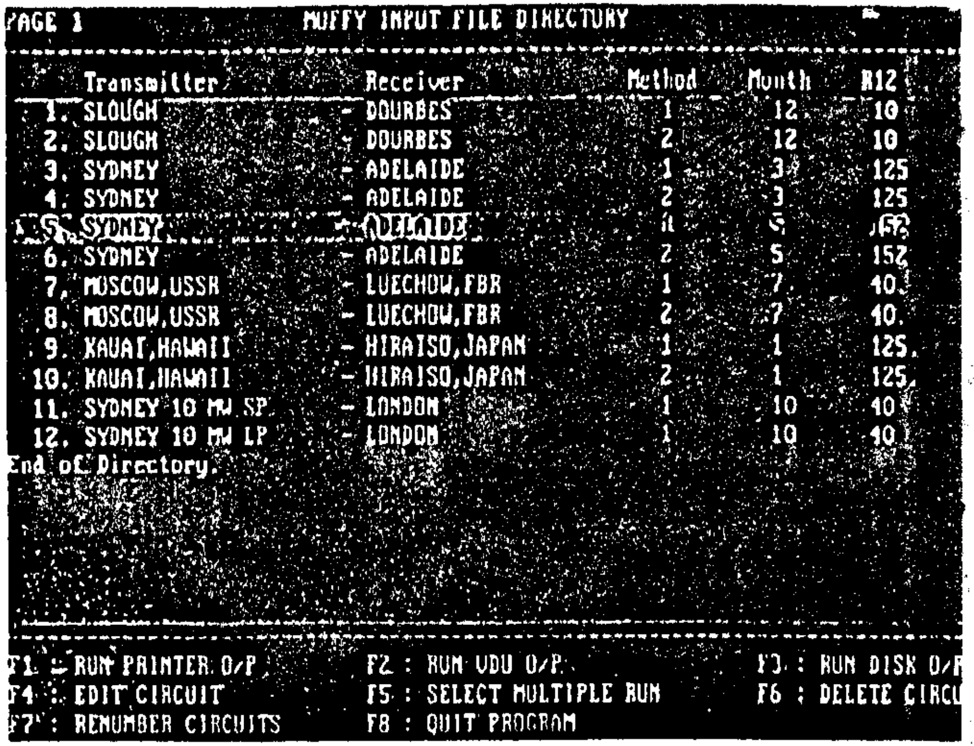

Figure 1 Example of MUFFY input file display

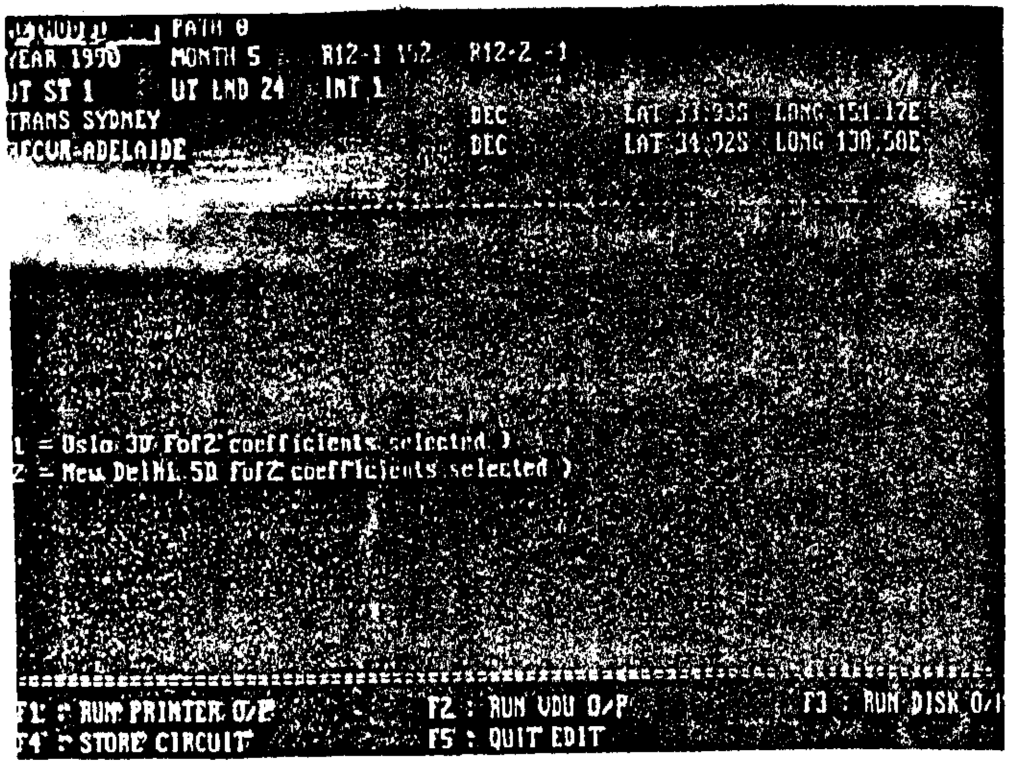

Figure 2 Example of edit display

BASIC MUF,OPERATIONAL MUF AND FOT DETERMINATION - CCIR REPORT 340-6

OSLO FOF2 COEFFICIENTS

MAY 1990 SUNSPOT NO. 152.0

SYDNEY 33.93S 151.17E TO ADELAIDE 34.92S 138.58E AZIMUTHS 261.01 88.15 MILES 720.4 KM. 1159.3

SHORT PATH TX PWR 1.0 KW

UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT
01	19.8	21.7	18.5	09	12.6	15.1	12.9	17	7.5	9.0	7.6
02	19.9	21.9	18.6	10	10.7	12.8	10.9	18	6.7	8.0	6.8
03	19.9	21.9	18.6	11	9.2	11.1	9.4	19	5.8	7.0	6.0
04	19.7	21.6	18.4	12	8.1	9.8	8.3	20	6.4	7.7	6.5
05	19.4	21.4	18.2	13	7.7	9.2	7.8	21	9.6	10.5	9.0
06	19.0	20.9	17.8	14	7.7	9.2	7.8	22	14.4	15.9	13.5
07	17.6	19.3	16.4	15	7.8	9.4	8.0	23	18.2	20.0	17.0
08	15.1	16.6	14.1	16	7.8	9.4	8.0	24	19.6	21.5	18.3

Figure 3 Example of output for path length less than 4000 km (Oslo foF2)

PROGRAM 'MUFFY' -JULY 90

BASIC MUF,OPERATIONAL MUF AND FOT DETERMINATION - CCIR REPORT 340-6

NEW DELHI FOF2 COEFFICIENTS

MAY 1990 SUNSPOT NO. 152.0

SYDNEY		TO ADELAIDE		AZIMUTHS	MILES	KM.
33.93S	151.17E	34.92S	138.58E	261.01 88.15	720.4	1159.3

SHORT PATH TX PWR 1.0 KW

UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT
01	20.8	22.9	19.4	09	13.6	16.4	13.9	17	8.8	10.6	9.0
02	20.5	22.6	19.2	10	12.0	14.4	12.2	18	8.1	9.7	8.2
03	20.2	22.2	18.9	11	10.6	12.8	10.8	19	7.1	8.5	7.3
04	19.8	21.8	18.5	12	9.6	11.5	9.7	20	7.5	9.1	7.7
05	19.7	21.6	18.4	13	9.0	10.8	9.2	21	10.7	11.7	10.0
06	19.3	21.2	18.0	14	8.9	10.7	9.1	22	15.6	17.1	14.6
07	18.0	19.8	16.8	15	9.0	10.8	9.2	23	19.4	21.4	18.2
08	15.8	17.4	14.8	16	9.1	10.9	9.2	24	20.8	22.9	19.5

Figure 4 Example of output for path length less than 4000 km (New Delhi foF2)

PROGRAM 'MUFFY' -JULY 90

BASIC MUF,OPERATIONAL MUF AND FOT DETERMINATION - CCIR REPORT 340-6

OSLO FOF2 COEFFICIENTS

JANUARY 1979 SUNSPOT NO. 125.0

KAUAI,HAWAII		TO HIRAISO,JAPAN		AZIMUTHS	MILES	KM.
22.00N	159.80W	36.40N	140.60E	299.80 88.35	3671.5	5908.4

SHORT PATH TX PWR 100.0 KW

UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT
01				09				17			
02	36.3	45.4	38.6	10	15.4	20.8	17.7	18	9.3	12.6	10.7
03				11				19			
04	35.4	44.3	37.6	12	12.2	16.5	14.1	20	20.2	25.2	21.4
05				13				21			
06	26.8	33.5	28.4	14	11.5	15.6	13.2	22	35.3	44.1	37.5
07				15				23			
08	21.6	29.2	24.8	16	9.6	13.0	11.1	24	37.7	47.1	40.1

Figure 5 Example of output for path length greater than 4000 km (Oslo foF2)

PROGRAM 'MUFFY' -JULY 90

BASIC MUF,OPERATIONAL MUF AND FOT DETERMINATION - CCIR REPORT 340-6

OSLO FOF2 COEFFICIENTS

OCTOBER 1990 SUNSPOT NO. 40.0

SYDNEY 10 MW LP TO LONDON AZIMUTHS MILES KM.
33.83S 151.17E 51.00N 0.10W 138.19 241.63 14302.8 23017.0

LONG PATH TX PWR 10.0 MW

UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT
01	11.2	14.5	12.3	09	17.1	22.2	18.8	17	8.5	10.3	8.7
02	12.4	16.1	13.7	10	15.0	18.0	15.3	18	10.7	12.8	10.9
03	13.2	17.1	14.6	11	13.3	16.0	13.6	19	14.1	16.9	14.4
04	11.9	15.5	13.2	12	12.2	14.6	12.5	20	16.7	20.1	17.1
05	9.8	12.7	10.8	13	11.5	13.8	11.7	21	16.6	19.9	16.9
06	9.8	12.7	10.8	14	10.9	13.1	11.1	22	13.9	16.7	14.2
07	13.3	17.3	14.7	15	9.9	11.8	10.1	23	12.3	14.7	12.5
08	18.7	24.4	20.7	16	8.6	10.4	8.8	24	11.2	13.4	11.4

OCTOBER 1990 SUNSPOT NO. 140.0

UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT	UT	BMUF	MUF	FOT
01	16.3	21.1	18.0	09	26.3	34.2	29.0	17	14.9	17.9	15.2
02	17.3	22.5	19.1	10	24.6	29.5	25.1	18	16.7	20.0	17.0
03	18.2	23.7	20.1	11	23.4	28.1	23.9	19	20.8	25.0	21.3
04	16.6	21.6	18.4	12	22.1	26.6	22.6	20	24.8	29.8	25.3
05	13.6	17.7	15.1	13	20.6	24.7	21.0	21	25.0	30.0	25.5
06	13.4	17.5	14.9	14	19.0	22.8	19.4	22	21.8	26.1	22.2
07	18.5	24.0	20.4	15	17.4	20.9	17.7	23	19.2	23.0	19.6
08	26.5	34.4	29.3	16	15.7	18.8	16.0	24	17.0	20.5	17.4

Figure 6 Example of output for a long great circle path (Oslo foF2)

Program HFANT-6

HFANT-6 is the current version of a program written in Microsoft Basic for PC evaluation giving the radiation patterns and directivity gains of a range of antenna types in common use at HF, particularly for broadcasting. The program is still under development and follows technical procedures generated within a specialist CCIR Working Party of antenna experts. The types of antenna available are:

1 MULTIBAND CENTRE-FED HALF-WAVE DIPOLE ARRAY......
2 DUAL-BAND CENTRE-FED HALF-WAVE DIPOLE ARRAY......
3 DUAL-BAND END-FED HALF-WAVE DIPOLE ARRAYS........
4 TROPICAL ARRAYS..................................
5 HORIZONTAL LOG-PERIODIC ARRAYS...................
6 VERTICAL LOG-PERIODIC ARRAYS.....................
7 HORIZONTAL RHOMBICS..............................
8 QUADRANT ANTENNAS................................
9 CROSSED-DIPOLE ANTENNAS..........................
10 VERTICAL MONOPOLES...............................

A description of these types and their usage is given in the Annex.

Formulae for the relative radiation in different azimuths and elevation angles are incorporated for these different antenna types on the assumptions that they are situated on flat homogenous imperfect ground, have radiating elements consisting of thin linear wires with sinusoidal current distributions. Directivity gain is obtained by numerical integration over a sphere.

The program is supplied with inbuilt full operating instructions for the selection of the antenna type, its dimensions, frequency, ground properties etc as input (Fig 1) and to specify the types of output required (Fig 2). The full gain can take several minutes of computation depending on the PC used and is available as an option. Both tabular and graphical azimuthal patterns (Figs 3 and 4) and elevation patterns (Figs 5 and 6) are provided. There is also the so-called Sanson-Flamsteed presentation giving simultaneous elevation and azimuth graphical data (Fig 7).

PAB/MID
January 1991

.... GENERAL ANTENNA DATA ....

```
Antenna system file (.DAT) ..................:  ANT2A
Antenna type ................................:  2BAND CNT.FD TUN.REF. AR.
Ground dielectric constant (3 - 80)..........:   4
Ground conductivity (.00003 - 5.0 S/m).......:  .01000
Operating frequency (2 - 30 MHz).............:  10.0
Number of elements in the same row (9 max)...:  1
Number of elements in the same stack (9 max).:  1
Design frequency (2 - 30 MHz)................:  10.0
Height above ground (0.10 - 9.99 wavelength).:  0.50
Slew angle (0 - 30 deg)......................:   0
Current ratio (0.1 - 0.9)....................:  .7

Elevation angle at maximum gain.........(deg):  27
Azimuth angle at maximum gain...........(deg):   0
Directivity gain (ref. to isotropic).....(dB):  10.6


> Strike any key to continue <            > Enter <P> for printouts <
```

FIG. 1

```
********** SELECT ONE OF THE FOLLOWING OPTIONS **********

irectivity gain and general antenna data.....(Enter <1>)
ertical pattern at given azimuth.............(Enter <2>)
orizontal pattern at given elevation.........(Enter <3>)
elative gain values at given directions......(Enter <4>)
ull antenna pattern calculation and filing...(Enter <5>)
anson-Flamsteed display of filed pattern.....(Enter <6>)

ETURN TO MAIN MENU...........................(Enter <RET>)

                         » «
```

FIG 2

AZ. (deg)	ATT. (dB)	AZ. (deg)	ATT. (dB)	AZ. (deg)	ATT. (dB)	AZ. (deg)	ATT. (dB)	AZ. (deg)	ATT. (dB)	AZ. (deg)	ATT. (dB)
1	0.02	16	4.98	31	30.00	46	15.80	61	22.73	76	30.00
2	0.07	17	5.70	32	28.07	47	15.96	62	23.50	77	30.00
3	0.16	18	6.40	33	24.24	48	16.16	63	24.32	78	30.00
4	0.29	19	7.35	34	21.83	49	16.42	64	25.18	79	30.00
5	0.45	20	8.30	35	20.15	50	16.72	65	26.07	80	30.00
6	0.65	21	9.35	36	18.91	51	17.06	66	27.01	81	30.00
7	0.89	22	10.53	37	17.97	52	17.45	67	28.00	82	30.00
8	1.16	23	11.84	38	17.25	53	17.88	68	29.02	83	30.00
9	1.48	24	13.34	39	16.71	54	18.35	69	30.00	84	30.00
10	1.84	25	15.07	40	16.30	55	18.86	70	30.00	85	30.00
11	2.24	26	17.12	41	16.01	56	19.41	71	30.00	86	30.00
12	2.69	27	19.64	42	15.82	57	20.00	72	30.00	87	30.00
13	3.18	28	22.97	43	15.71	58	20.62	73	30.00	88	30.00
14	3.73	29	27.95	44	15.67	59	21.28	74	30.00	89	30.00
15	4.32	30	30.00	45	15.71	60	21.99	75	30.00	90	30.00

> Strike any key to continue <

FIG 3

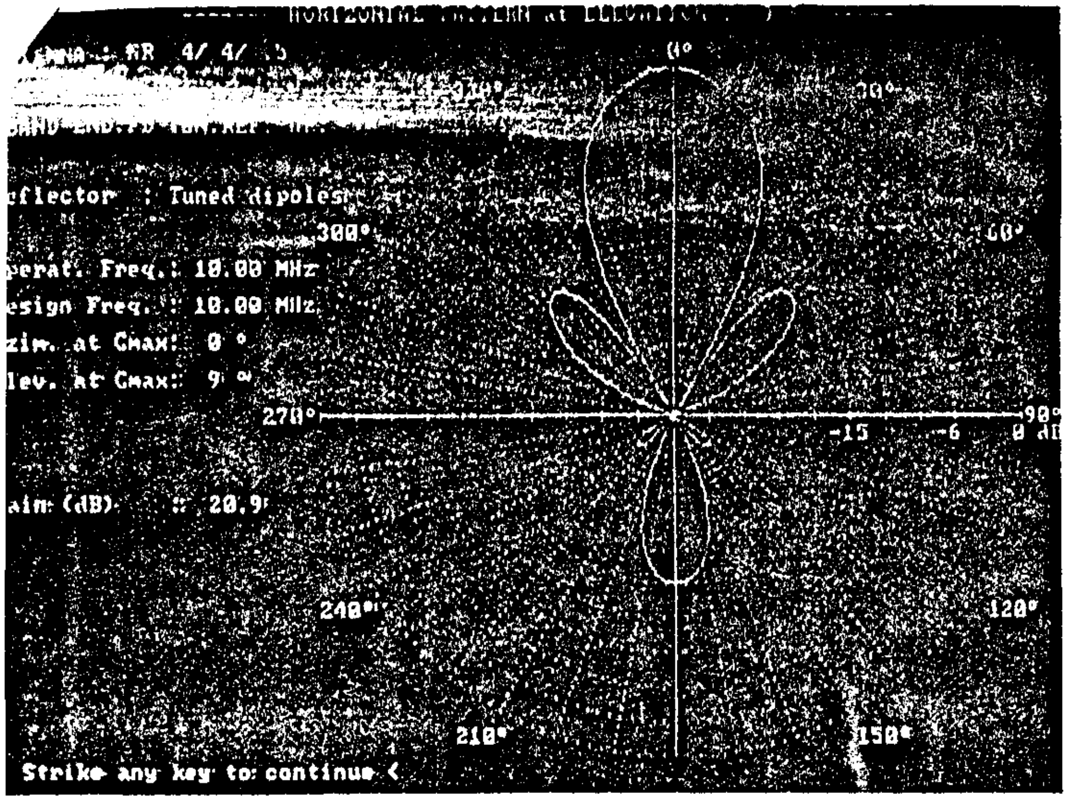

FIG 4

EL. (deg)	ATT. (dB)	EL. (deg)	ATT. (dB)	EL. (deg)	ATT. (dB)	EL. (deg)	ATT. (dB)	EL. (deg)	ATT. (dB)	EL. (deg)	ATT. (dB)
1	15.12	16	4.87	31	30.00	46	16.36	61	18.29	76	27.61
2	9.26	17	6.55	32	23.78	47	17.86	62	18.25	77	28.94
3	5.99	18	8.60	33	20.13	48	19.72	63	18.33	78	30.00
4	3.84	19	11.11	34	17.66	49	22.02	64	18.53	79	30.00
5	2.34	20	14.27	35	15.89	50	24.76	65	18.82	80	30.00
6	1.29	21	18.45	36	14.60	51	27.44	66	19.20	81	30.00
7	0.59	22	24.53	37	13.69	52	28.22	67	19.68	82	30.00
8	0.17	23	30.00	38	13.08	53	26.50	68	20.23	83	30.00
9	0.00	24	28.67	39	12.73	54	24.31	69	20.87	84	30.00
10	0.05	25	25.09	40	12.60	55	22.48	70	21.58	85	30.00
11	0.31	26	23.91	41	12.69	56	21.10	71	22.38	86	30.00
12	0.78	27	24.32	42	12.99	57	20.06	72	23.25	87	30.00
13	1.46	28	26.38	43	13.50	58	19.32	73	24.21	88	30.00
14	2.35	29	30.00	44	14.21	59	18.80	74	25.25	89	30.00
15	3.48	30	30.00	45	15.16	60	18.46	75	26.38	90	30.00

> Strike any key to continue < > Enter (F) to file data <

FIG 5

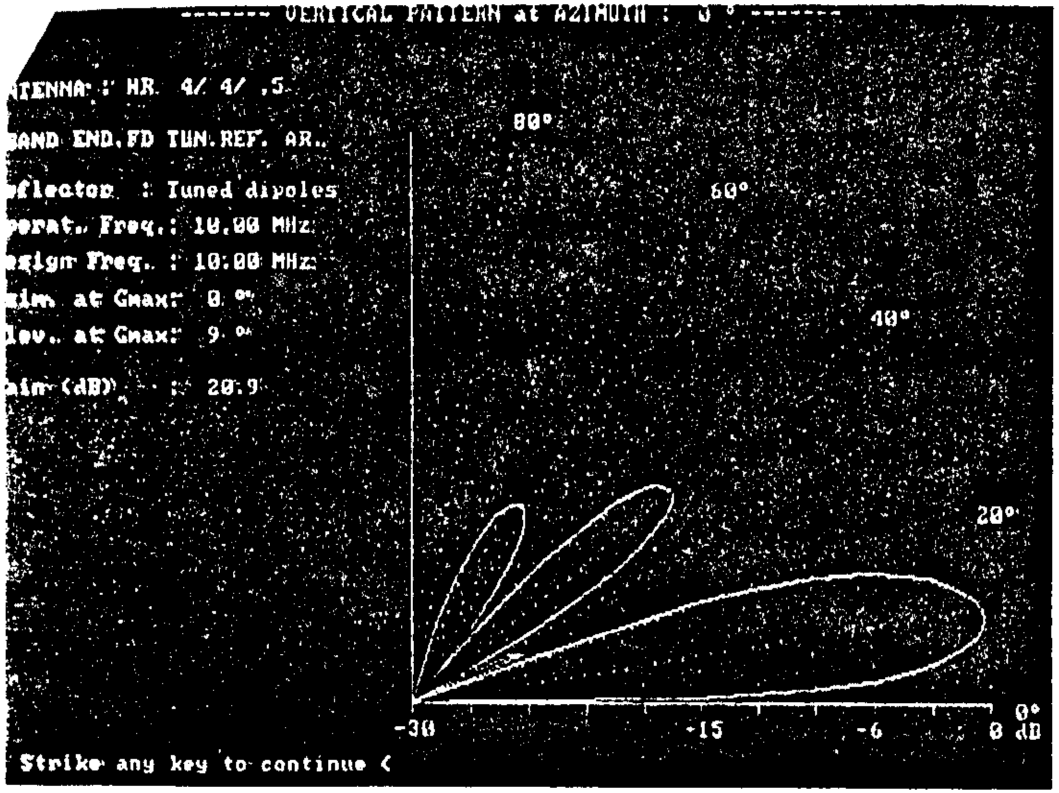
------- VERTICAL PATTERN at AZIMUTH : 0 ° -------
NTENNA : HR 4/ 4/ ,5
BAND END.FD TUN.REF. AR.
flector : Tuned dipoles
erat. Freq. : 10.00 MHz
esign Freq. : 10.00 MHz
zim. at Gmax: 0 °
lev. at Gmax: 9 °
ain (dB) : 20.9
80°
60°
40°
20°
0°
-30
-15
-6
0 dB
Strike any key to continue <

FIG 6.

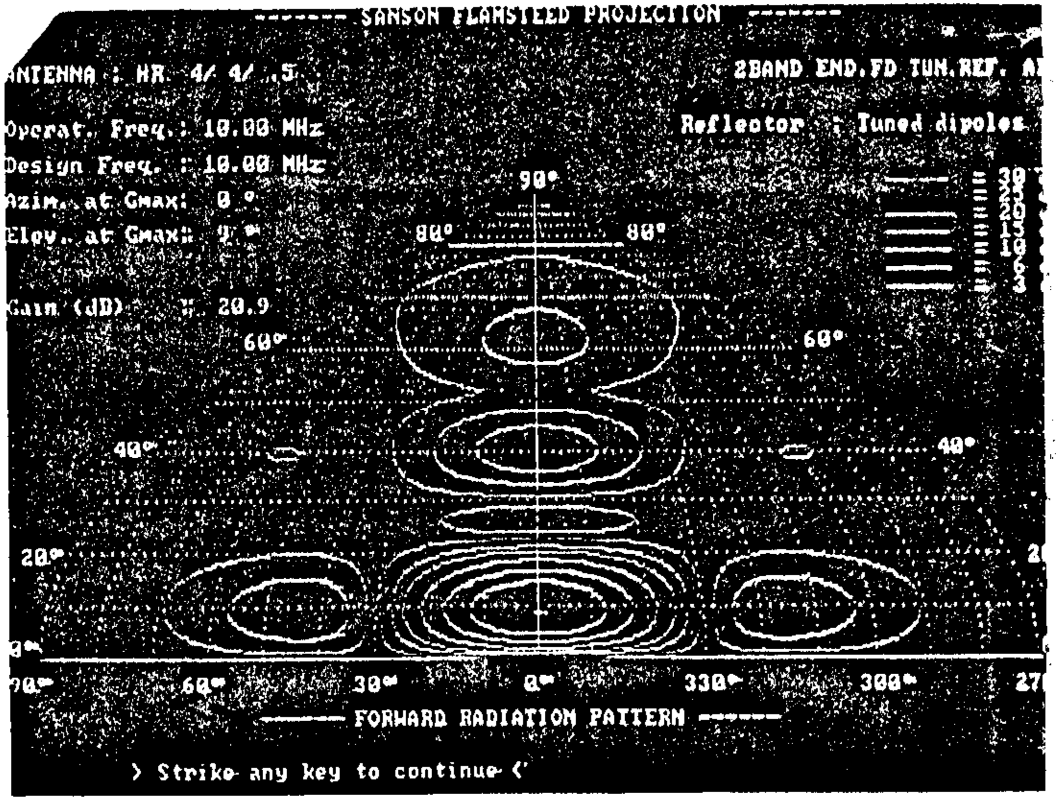
------- SANSON FLAMSTEED PROJECTION -------
ANTENNA : HR 4/ 4/ ,5
2BAND END.FD TUN.REF. A
Operat. Freq. : 10.00 MHz
Reflector : Tuned dipoles
Design Freq. : 10.00 MHz
Azim. at Gmax: 0 °
Elev. at Gmax: 9 °
Gain (dB) : 20.9
90°
80°
60°
40°
20°
0°
30
60°
30°
0°
330°
300°
------- FORWARD RADIATION PATTERN -------
> Strike any key to continue <

FIG 7

ANNEX

Choice of optimum antennas for various types of service

The chart in Figure A.1 gives some general guidelines for the choice of suitable antennas for a given type of service according to the required distance range. Two different categories are considered : short distance and medium/long-distance services.

A short distance service is understood here to have a range of up to about 2,000km. The corresponding area can be covered with either a non-directional or a directional antenna whose beamwidth can be selected according to the width of the sector to be served. In the case of directional antennas, both horizontal dipole curtain and log periodic antennas can be employed. The latter type is a multiband array with a wide operating frequency range, a low-to-medium gain and large horizontal beamwidth.

Medium and long distance services can be considered to have a range beyond about 2,000 km. Such coverage can be provided by antennas whose main-lobe elevation angle is small (6°-13°) and whose horizontal beamwidth - depending on the width of the area to be served as seen from the transmitter - is either wide between 65° and 95° (generally 70°) or narrow between 30° and 45° (generally 35°).

Transmitting Antennas

Arrays of Horizontal Dipoles

The half wavelength dipole is one of the radiating elements most commonly used at HF. Horizontal dipoles can be used on their own, or more often as arrays of dipoles arranged collinearly and/or in parallel.

Arrays of horizontal dipoles are used to obtain:-

- increased gain;
- improved directivity.
- sleving of main beam

Higher gains are achieved by arranging the dipole elements collinearly and/or stacking parallel dipoles in order to reduce the beamwidth of the main lobe and hence increase the directivity of the antenna.

The main beam of some horizontal dipole arrays which have more than one feed point may be electrically sleved by feeding each stack or row of dipoles with equal currents having different phases.

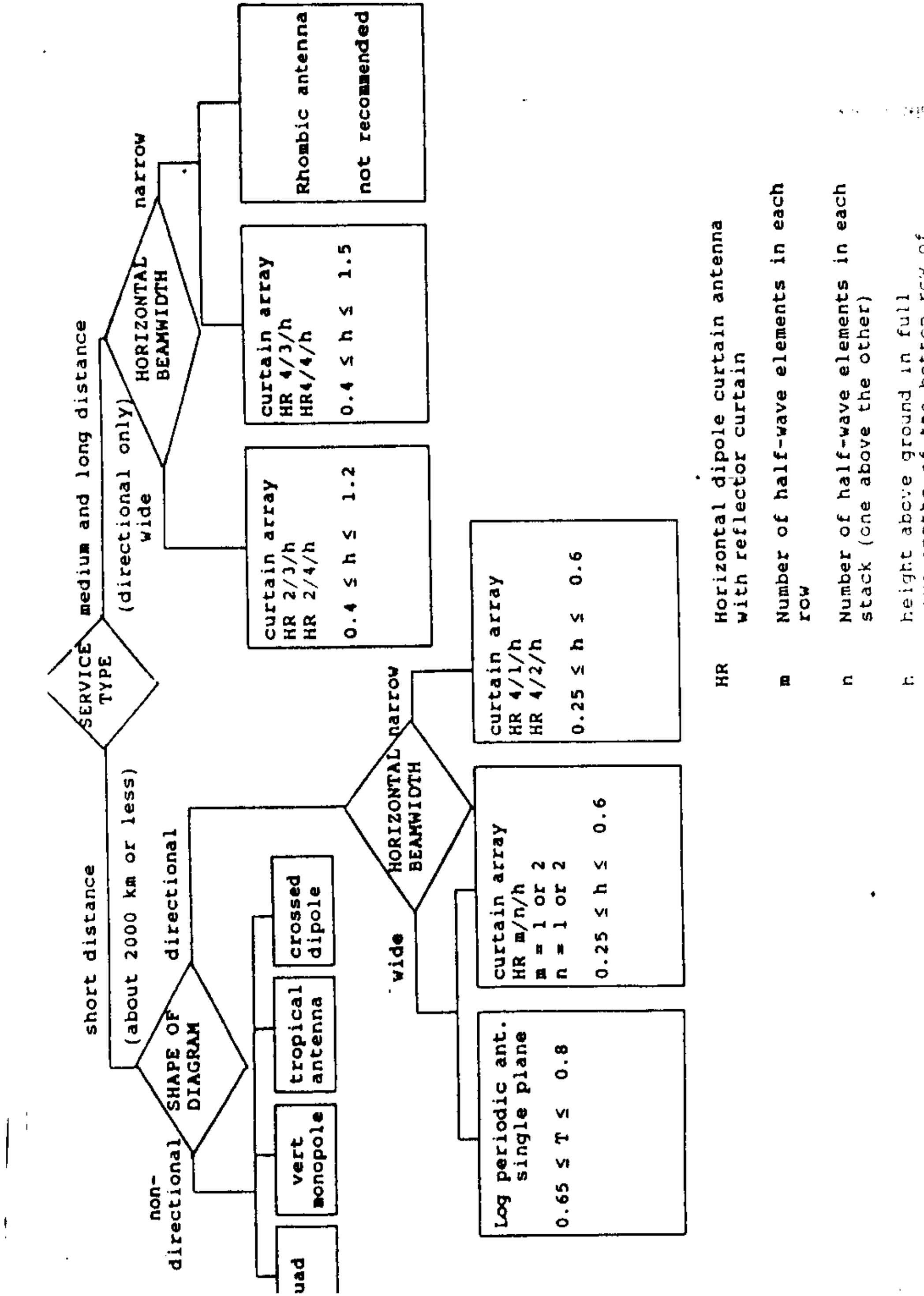

Figure A.1
Antenna Planning Chart

Unidirectional patterns are generally obtained by the use of a reflector. This reflector can be comprised of either:

a) an identical array of dipoles tuned to provide an optimum front-to-back ratio over a limited range of operating frequencies. This type of reflector is known as a "tuned dipole" or "parasitic" reflector.

or

b) a screen consisting of horizontal wires which act as an untuned reflector. This type of reflector is known as an "aperiodic" or "screen" reflector.

Non-directional short-range coverage in HF broadcasting generally requires the use of omnidirectional or near-omnidirectional antennas.

Arrays of horizontal dipoles arranged vertically

Arrays of horizontal dipoles arranged vertically (curtain antennas) are realized by aligning and/or stacking half wavelength dipoles in a vertical plane.

Two different basic feeding arrangements are used.

- centre-fed dipoles;
- end-fed dipoles.

In the centre-fed array, the dipole element has its own feeding point. Antennas with a number of pairs of half-wavelength dipoles in a row greater or equal to two, can be slewed.

In the end-fed array, two adjacent dipoles offer a common feeding point connected to a single transmission line. Slewing capability is provided only for cases when the number of the pairs of half-wavelength dipoles in a row is even.

Curtain antennas using centre-fed elements are of more modern design and, as the cost of a mote complex feeding arrangement, offer greater slewing capabilities when compared to the corresponding end-fed type.

For example, and HR 4/.../... centre-fed dipole array with four feed points, can be slewed up to ±30° and still maintain acceptable side-lobe levels.

A corresponding HR 4/.../... end-fed dipole array provides only two feed points spaced at about one wavelength. This spacing and the related feeding system which sets up a phase difference between the two halves of the array, result in a practical slewing capability of about ±15° in the azimuthal plane. Greater slewing results in an undesirably large-amplitude sidelobe having a maximum gain value within 6 dB of that of the main beam.

The main features of a horizontally slewed antenna are:

- the main beam is no longer in the direction normal to the plane of the dipoles, nor is it symmetrical about the axis of the direction of the slewed maximum,
- the forward horizontal radiation pattern is no longer symmetrical with respect to the direction normal to the plane of the dipoles,
- the backward radiation pattern is no longer symmetrical with respect to the direction normal to the plane of the dipoles, nor is it on the axis of the direction of the slewed maximum in the forward pattern. Slewing the forward radiation of an antenna in one direction (e.g. clockwise) will cause the back radiation to slew in the opposite direction (i.e. anticlockwise).

Arrays of horizontal dipoles arranged horizontally

Radiation mainly concentrated at high elevation angles (up to 90°) and in most cases associated with a nearly circular azimuthal radiation patterns is achieved by using arrays of horizontal dipoles in a plane parallel to and at a given height above the ground.

These antennas, also called tropical antennas, are often used for short-range broadcasting in tropical zones and consist of one or more rows of half-wave horizontal dipoles at a height above ground usually not exceeding 0.5 wavelength.

Slewing of the main beam can be achieved by varying the phases of the feed current in the elements of the same row.

The resulting pattern then shows a more or less pronounced main beam tilt thus providing a directional effect useful for specific coverage situations.

Omnidirectional arrays of horizontal dipoles

Quadrant antennas

The simplest form of quadrant antenna is represented by an arrangement of two end-fed half-wave dipoles placed at a right angle. Another form of quadrant antenna sometimes encountered in practice, consists of four elements placed at right angles in a box formation and fed at opposite angles.

Quadrant antennas may also be stacked to achieve a more directive vertical radiation pattern and a higher directivity gain.

Crossed dipole antenna

A crossed-dipole antenna consists of two centre-fed half-wave dipoles placed at a right angle to form a cross. The intersection point coincides with the radiating element feed point.

Log-periodic antennas

Log-periodic dipole arrays are tapered linear arrays of dipole elements of varying length which operate over a wide frequency range. Wide band operation is achieved by assuming that different groups of elements radiate at different frequencies. The spacing between the elements is proportional to their length and the system is fed using a transmission line. As the frequency ratio varies, the elements which are at or near resonance, couple energy from the transmission line. The resulting radiation pattern is directional and has a broadly constant characteristic over the full operating frequency range.

The usable bandwidth of the antenna depends on the relative bandwidth the antenna can cover before unacceptable effects are caused by the smallest or largest element.

Rhombic antennas

A Rhombic antenna consists of four straight wires of the same length arranged in the form of a rhombus. A typical rhombic antenna has side lengths of a few wavelengths and has a height of between 0.5-1.0 λ at the middle of the operating frequency range.

The rhombic antenna differs from the array of dipoles since it belongs to the travelling-wave antenna category, i.e. the currents in the conductors of the antenna are substantially travelling waves originated from the feeding point and propagating through the wires towards the terminating resistance.

A considerable amount of power may be lost in the terminating resistance and represents the price that has to be paid for some desirable features such as simplicity of construction, relatively wide bandwidth of operation and high directivity gain.

The rhombic antenna has been extensively used for HF broadcasting but is no longer recommended for this purpose as:

- the main lobe is narrow in both horizontal and vertical planes which could result in the required service are not being reliably covered because of the variations in the ionosphere;
- there are a large number of sidelobes of a size sufficient to cause interference to other broadcasts;
- a significant proportion of the transmitter power is dissipated in the terminating impedance and in the sidelobes.

Vertical monopoles

Vertical monopoles are seldom used in HF broadcasting due to their low gain and non-directional properties. Their main application is confined to short-range omnidirectional broadcasting where economical and/or site constraints do not allow for the installation of radiating structures with better performance.

Program REP-894

This program, following the technical procedure of CCIR Report 894, calculates basic MUF, signal field strength, signal/noise ratio and basic circuit reliability at HF on a point-to-point ionospheric link for a series of input frequencies at a number of different UT in a given year-month. Because the calculations involve a lot of input numbers a cursor-interactive display with prompts is provided. Since too, often there is a requirement to change only a limited number of input values for successive calculations, eg for a later year and month, input data sets can be assembled and stored in a directory for subsequent use.

PAB/MID
January 1991

Input data

Parameters required to specify a circuit

Input data requirements are as indicated below. Units in which quantities are expressed as shown on the display.

Circuit/operational parameters

(i) Latitude and longitude of the transmitter and receiver.
(ii) Month, smoothed sunspot number and calendar year.
(iii) Frequencies (maximum number 10).
(iv) Universal Time.

System parameters

(i) Transmitter power, minimum angle of elevation to be considered, transmitter antenna type and boresight bearing.
(ii) Receiver bandwidth and required S/N ratio; percentage of the days of the month for which the required S/N ratio must be attained; receiver antenna type and bearing.

Noise background at receiver

Man-made noise environmental category or measured noise intensity.

Antenna types

The edit display lists antenna types for which the gain is specified in an antenna package supplied (see Table 1 for additional information). The program allows only transmitting antennae. Use of an isotropic receiving antenna is assumed.

Required output option

Five separate printout forms are provided together with one RAL graphics output and six CNET graphics outputs.

Cursor-interactive input

Three displays are provided

(i) An input file display listing the circuit data sub-sets of those circuits held in the directory. (Figure 1).
(ii) An edit display which lists all the parameters of a given circuit data set. (Figure 2).
(iii) A multiple run display which can be composed in order to perform successive calculations for particular circuit combinations. (This can also be used for a single circuit).

A selection of operations as described below, is available with these displays.

On loading REP894-2 a Turbo Pascal program (INP894Y.EXE) is called and the input file display is viewed.

Calculations can be performed in input file display mode, multiple circuit run mode or edit display mode.

Input file display mode

With the cursor keys an individual circuit can be highlighted and then using the function keys F1-F8 various operations performed on it.

Cursor highlighting actions are as follows:

Up arrow: moves cursor upwards one circuit in list
Down arrow: moves cursor downwards one circuit
Page up: moves cursor to first circuit on next page
Page down: moves cursor to first circuit on previous page
Home: moves cursor to first circuit in directory
End: moves cursor to last circuit in directory

Pressing the RETURN key also moves the cursor downwards one entry.

The designation of the function keys for individual circuit operation is:

F1. Performs calculations and sends output to printer
F2. Performs calculations and sends output to the VDU
F3. Performs calculations and sends output to a disk file
F4. Enters edit display and run mode
F5. Enters multiple circuit assembly and run mode
F6. Deletes the circuit data set from the directory
F7. Renumbers circuit data sets
F8. Quits program

Multiple-circuit assembly and run mode

This facility, which is entered by pressing key F5, provides batch running of up to 30 circuits at a time. Batches are assembled and run. For assembly, circuits included in the directory are reviewed by placing the cursor over the circuit name using the arrow keys. A particular circuit is selected by pressing key F4 (in which case a highlighted number appears next to the circuit name and the cursor moves automatically to the next circuit of the directory). The running total of number of circuits selected appears in the top right-hand corner of the screen.

The designation of the function keys for multiple circuit section and running is:

F1. Runs multiple circuits and sends output to printer
F2. Runs multiple circuits and sends output to VDU
F3. Runs multiple circuits and sends output to a disk file
F4. Selects a circuit for a multiple run
F5. Quits multiple run selection facility

Edit display and run mode

After pressing the F4 key whilst in the input file display a new screen display appears giving in the top half a listing of parameters for the previously highlighted circuit. The cursor appears highlighting the first parameter (the Method).

Parameters are reviewed by using the arrow key commands: These are

as follows:

Up arrow: moves upwards one parameter
Down arrow: moves downwards one parameter
Left arrow: moves back one parameter in list
Right arrow: moves onto next parameter in list
Also the RETURN key moves onto next parameter in list.

Every time the cursor is moved a corresponding message is displayed towards the bottom half of the screen, explaining what the parameter is and advising the user regarding the limits imposed and units to be used. To change a parameter just move the cursor over it and type in the new value, followed by a 'RETURN'. A small message appears in mid-screen to advise of invalid entries, in which case enter again until the value is valid.

The backspace key can be used to delete a character.

An example of edit display formats is shown in Figure 2.

In the edit display and run mode the function keys are employed as follows:

F1. Performs calculations for viewed circuit and sends output to printer
F2. Performs calculations for viewed circuit and sends output to VDU
F3. Performs calculations for viewed circuit and sends output to a disk file
F4. Stores edited circuit data set in input file directory
F5. Quits edit mode and returns to input file display mode

Antenna characteristics

The program incorporates a transmitting antenna gain package for a number of common antennas used in HF broadcasting (see Table 1). These are arrays of half-wave dipoles with or without reflector:

- Arrays of horizontal half-wave dipoles without reflector are designated as H m/n/h

- Arrays of horizontal half-wave dipoles with passive reflecting elements of identical geometrical structure situated at a distance of λ/4 behind the main antenna are designated as HR m/n/h, where λ is the wavelength.

  . m is the number of half-wave dipoles in each row
  . n is the number of rows spaced half a wavelength apart one above the other
  . h is the height above the ground in fractions of wavelength of the bottom row of dipoles.

Two other antennas are also included.

- isotropic antenna

- vertical half-wave dipole over a perfect ground

Transmitter and receiver coordinate representations

The compass pointing (N, E, S, W) may be immediately before or after the numerical coordinate or, following IFRB practice, between the integer and fractional parts. Examples of these three forms are N51.56,51.56N and 51N56 respectively. The quantities N52 and 52N are interpreted as 52 degrees north. These options are additional to be ability to input coordinates either in decimal degrees or degrees and minutes.

Table 1   Antenna types

Antenna number	Type	Total horizontal beamwidth (°)	Gain (dBi)	Elevation of beam maximum (°)
0	Isotropic	360 (-3 dB)	0	-
1	HR 4/4/1	35 (-6 dB)	22	7
2	HR 4/4/0.8	35 (-6 dB)	22	8
3	HR 4/4/0.5	35 (-6 dB)	21	9
4	HR 4/3/0.5	35 (-6 dB)	20	12
5	HR 4/2/0.5	35 (-6 dB)	19	17
6	HR 4/2/0.25	35 (-6 dB)	18	23
7	HR 2/4/1	70 (-6 dB)	19	7
8	HR 2/4/0.8	70 (-6 dB)	19	8
9	HR 2/4/0.5	70 (-6 dB)	19	9
10	HR 2/3/0.5	70 (-6 dB)	18	12
11	HR 2/2/0.5	70 (-6 dB)	16	17
12	HR 2/2/0.25	70 (-6 dB)	15	23
13	HR 1/2/0.5	110 (-6 dB)	14	17
14	HR 1/1/0.5	80 (-3 dB)	11	30
15	H 1/1/0.5	80 (-3 dB)	8	30
16	Vertical	360 (-3 dB)	4	30
17	HR 1/1/0.25	128 (-3 dB)	10	56
18	HR 2/1/0.25	85 (-3 dB)	11	56
19	HR 2/1/0.5	55 (-3 dB)	13	30
20	HR 1/2/0.25	83 (-3 dB)	12.5	23
21	H 1/1/0.3	360 (-3 dB)	7	56
22	H 1/1/0.4	100 (-3 dB)	7	39
23	H 1/1/0.5	93 (-3 dB)	8.5	30

- Output data

Five printout options and one RAL graphics output option are provided embedded in the program together with a CNET stand-alone graphics package yielding six separate output options.

Embedded output options

With each of the options indicated in Table 2 data are presented for each selected UT and frequency. Field strengths, signal/noise ratios and MUF's are monthly median values except with Methods 2 and 3 where the predicted signal/noise ratio is for a user specified required percentage of the days of the month.

Table 2 Embedded output options

Method	Parameters
1	skywave field strength
2	signal/noise ratio
3	frequencies with monthly median signal/noise ratio exceeding required value
4	best frequency from those of an input list
5	graphical presentation of the times for which user specified frequencies are likely to propagate
6	extended output

The following 5 lines of header information are common to all outputs.

- line 1 : output method : method = 1, 2, 3, 4, 5, 6
  program version : is REP894-2 vers 1.02 24.JAN.90
- line 2 : month, year, smoothed sunspot number
- line 3 : circuit identification : transmitter and receiver names
- line 4 : transmitter and receiver geographical coordinates, azimuths, path lengths in nautical miles and in km

- line 5 : minimum angle of elevation (degrees)
  transmitter power (kW)
  standardisation factors LZ and LY (dB)
  start of transition distance (7000 km)

In addition there are:

- line 6: antenna type and bearings for transmitter and receiver (line 6 is not available with Method 5)
- line 7: percentage of days for which the required signal/noise ratio must be attained at the LUF (taken in the present program to be 50), man-made noise environmental category (1-4) or user specified 3 MHz noise power in dBw, receiver bandwidth in Hz, and required signal/noise ratio (line 7 is not available with outputs 4 and 5)

Method 1: RSS median skywave field strength

For each selected UT the following are tabulated

(i) MUF, basic maximum usable frequency (MHz)
(ii) RSS median field strength of the strongest mode in dB above 1μV/m of the MUF and for the different selected frequencies
(iii) LUF, lowest usable frequency (MHz)
(iv) FOT, optimum working frequency (MHz)
(v) OPMUF, operational MUF (MHz)

An example of this method is given in Figure 3.

Method 2: Signal/noise ratio for a required percentage of time

The format is identical to 4.1.1 except signal/noise ratios are given for the required percentage of time (between 10-90% of the month). Example of this method are given in Figure 4

Method 3: When a required signal/noise ratio is achieved

When the required signal/noise ratio, for the required percentage of days of the month, is achieved (or exceeded) this is shown by a *;

otherwise there is a blank space.

Method 4: Prediction of best usable frequency

The frequency from an input list closest to the FOT is tabulated providing the LUF is less than the operational MUF.

Method 5: RAL graphical presentation of LUF and operational MUF

Graphical presentation over 24-hours UT of the operational MUF, LUF and those frequencies from an input list, up to a maximum of 3 at a given hour, for which propagation is possible. Where more than 3 frequencies can propagate those closest to the FOT are given. Typing 'P' in response to the question 'Press any key...' enables this output to be printed on an online dot matrix printer. Any other response results either in calculations for the next circuit or a return to the input directory.

An example of this method is illustrated in Figure 5

Method 6: Extended output

In this tabulation (Figs 6 and 7) following the standard header information at each UT are:

- line 1 : FREQ : Universal Time (UT)
  basic maximum usable frequency, MUF (MHz)
  input frequency list (MHz)
  lowest usable frequency, LUF (MHz)
  optimum working frequency, FOT (MHz)
  operational MUF, OPMUF (MHz)

For the basic MUF and the selected frequencies those entries are followed by:

- line 2 : MODE : Number of hops and propagation mode
- line 3 : ANGL : Angle of elevation (degrees)

- line 4 : DBU : RSS median field strengths at the receiver (dB above 1µV/m)
- line 5 : S/N : Signal/noise ratios (dB)
- line 6 : PS/N : Probability that the required signal/noise ratio is achieved.

CNET stand-alone graphics output package

The graphics program CGRAPH, which is separate from the RAL graphics , requires as input the output data (CGRAPH.OUT) from Method 2 and permits separate colour presentation of the following quantities:

Circuit characteristics

The path and operating parameters of a single circuit are displayed.

Basic MUF, operational MUF, FOT and LUF

These parameters are displayed as a function of frequency for the hours 00-23 UT. An example is given in Figure 8 .

Field strength, noise power and signal/noise ratio

Histograms of these parameters are shown

(i) for the hours 00-23 UT for a frequency selected from an input list (Figure 9).
(ii) for all frequencies of the input list at a specified UT

Modes and angles of elevation

Histograms of these quantities are illustrated:

(i) for the hours 00-23 UT for a frequency selected from an input list
(ii) for all frequencies of the input list at a specified UT

References

Dick, M.I. (1990), 'Description of Disks of CCIR Numerical Ionospheric Reference Data'.
CCIR Resolution 63, SG-6, CCIR Secretariat, Geneva.

Jensen, D.C. and Cain, J.C. (1962), 'Interim Magnetic Field'. J. Geophys. Res. 9, 3568-3569.

Lucas, D.L. and Harper, J.D. (1965), 'A numerical representation of CCIR Report 322, high frequency (3-30 Mc/s) atmospheric radio noise data'. NBS Tech Note 318, US Government Pointing Office, Washington, D.C.

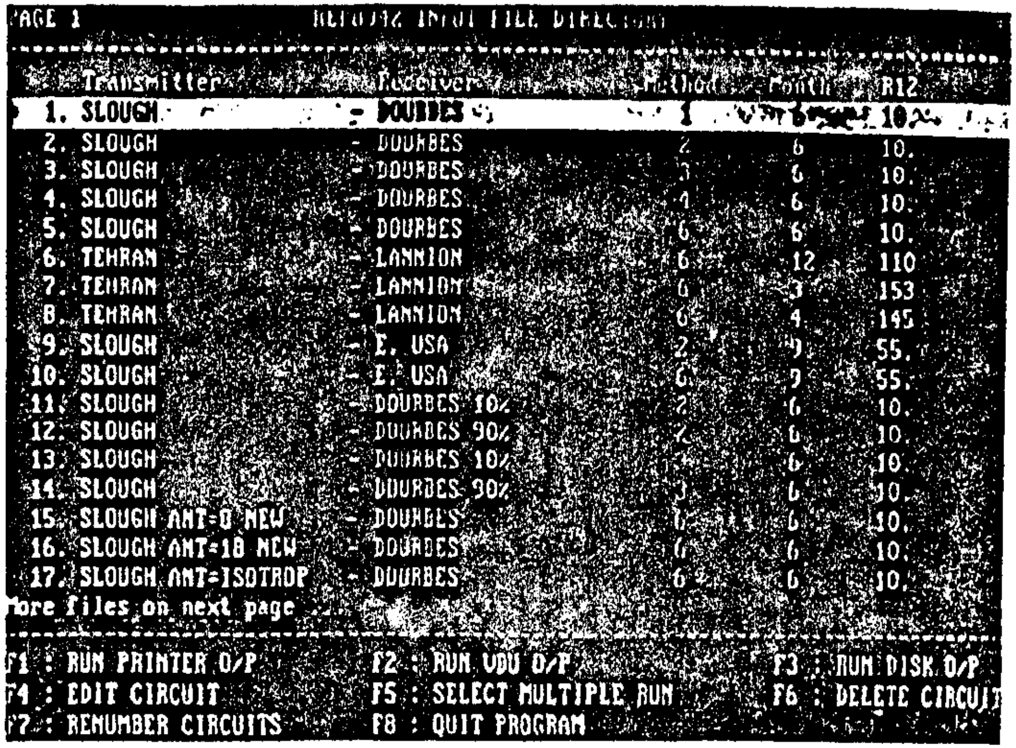

Figure 1: Example of REP8942 input file display

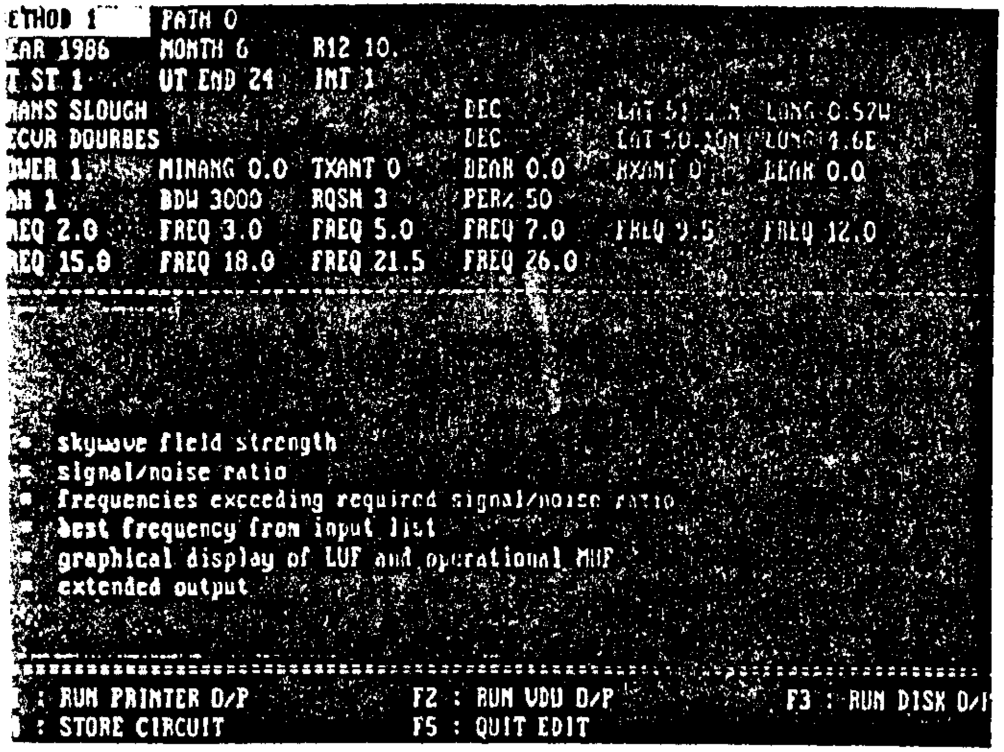

Figure 2: Example of edit display

METHOD 1 REP894-2 VER-1.02 24.JAN.90 PAGE 1

JUN 1986 SSN = 10.

SLOUCH DOURBES AZIMUTHS SP N. MI. KM
51.50 N 0.57 W 50.10 N 4.60 E 111.17 295.18 213.4 395.2
MIN ANG 3.0 DEG, PWR 1.00 KW, XLZ 2.8 DB, XLY -4.2 DB, FTZ DIST 7000. KM
TX-ANT ISOTROPIC TBEAR 0.0 RX-ANT ISOTROPIC RBEAR 0.0
LUF 50 NOISE CATEGORY 1 3000 HZ RX BDWTH REQ S/N 3 DB

MEDIAN FIELD STRENGTH FOR STRONGEST MODE IN DB ABOVE 1 UV/M ITS CODE

UT	MUF	DBU	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0	LUF	FOT	OPMUF
1	4.5	40	37	38	38	2	-34	-34	-33	-33	-33	-33	2.0	4.6	5.4
2	4.2	39	40	38	35	-16	-34	-34	-33	-33	-33	-33	2.0	4.0	4.7
3	4.2	39	40	38	34	-19	-34	-34	-33	-33	-33	-33	2.0	3.9	4.6
4	4.4	39	41	41	37	-3	-34	-33	-33	-33	-33	-32	2.0	4.2	4.9
5	4.9	38	36	39	38	13	-35	-34	-33	-33	-33	-33	2.0	4.5	5.3
6	5.3	36	29	32	39	24	-36	-35	-34	-34	-33	-33	2.0	4.9	5.8
7	5.7	34	20	25	35	29	-22	-37	-35	-35	-34	-34	2.0	5.3	6.2
8	6.0	33	12	19	32	30	-9	-37	-36	-35	-34	-34	2.4	5.7	6.6
9	6.2	34	5	14	30	30	-5	-38	-37	-36	-35	-34	3.0	5.9	6.7
10	6.4	33	-1	10	29	29	-7	-39	-37	-36	-35	-34	3.4	6.1	6.7
11	6.5	32	-4	8	28	28	-11	-39	-37	-36	-35	-34	3.7	6.2	6.6
12	6.5	31	-5	7	27	87	-14	-39	-37	-36	-35	-34	3.7	6.2	6.5
13	6.5	31	-4	8	27	26	-17	-40	-38	-36	-35	-35	3.6	6.2	6.5
14	6.4	32	0	11	29	26	-21	-39	-37	-36	-35	-35	3.4	6.1	6.4
15	6.2	33	6	15	30	26	-23	-38	-37	-36	-35	-34	2.9	5.9	6.2
16	5.9	33	12	18	30	25	-25	-40	-38	-38	-37	-37	2.4	5.6	6.2
17	5.8	32	20	24	33	28	-17	-39	-38	-37	-37	-36	2.0	5.4	6.4
18	6.2	35	28	33	33	33	-1	-38	-37	-37	-36	-36	2.0	5.8	6.8
19	6.6	38	35	37	37	37	14	-36	-36	-35	-35	-35	2.0	6.2	7.3
20	6.8	39	39	39	38	39	19	-33	-35	-35	-35	-35	2.0	6.4	7.5
21	6.6	39	38	37	38	38	13	-36	-35	-35	-35	-35	2.0	6.1	7.2
22	6.0	39	39	37	39	35	-7	-35	-35	-34	-34	-34	2.0	6.1	7.1
23	5.4	39	36	37	39	27	-34	-35	-35	-35	-34	-34	2.0	5.5	6.4
24	4.9	39	36	37	39	16	-35	-35	-35	-35	-34	-34	2.0	5.0	5.9

Figure 3: Example of Method 1 output

METHOD 2 REP894-2 VER-1.02 24.JAN.90 PAGE 2

JUN 1986 SSN = 10.

SLOUCH DOURBES AZIMUTHS SP N. MI. KM

51.50 N 0.57 W 50.10 N 4.60 E 111.17 295.18 213.4 395.2

MIN ANG 3.0 DEG, PWR 1.00 KW, XLZ 2.8 DB, XLY -4.2 DB, FTZ DIST 7000. KM

TX-ANT ISOTROPIC TBEAR 0.0 RX-ANT ISOTROPIC RBEAR 0.0

LUF 50 NOISE CATEGORY 1 3000 HZ RX BDWTH REQ S/N 3 DB

MEDIAN SIGNAL-TO-NOISE RATIO FOR STRONGEST MODE IN DB ITS CODE

UT	MUF	DB	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0	LUF	FOT	OPMUF
1	4.5	28	24	26	27	-8	-42	-40	-39	-38	-38	-37	2.0	4.6	5.4
2	4.2	28	27	26	24	-26	-42	-40	-39	-38	-38	-37	2.0	4.0	4.7
3	4.2	28	27	26	24	-29	-42	-41	-39	-38	-38	-37	2.0	3.9	4.6
4	4.4	29	28	30	27	-12	-42	-40	-39	-38	-37	-36	2.0	4.2	4.9
5	4.9	28	24	28	28	5	-42	-41	-39	-38	-37	-37	2.0	4.5	5.3
6	5.3	27	16	21	29	15	-44	-42	-40	-39	-38	-37	2.0	4.9	5.8
7	5.7	25	8	14	26	20	-29	-43	-41	-40	-39	-38	2.0	5.3	6.2
8	6.0	24	-1	8	23	22	-16	-44	-42	-40	-39	-38	2.4	5.7	6.6
9	6.2	25	-8	3	21	22	-12	-45	-42	-41	-39	-38	3.0	5.9	6.7
10	6.4	24	-13	-1	19	21	-14	-45	-43	-41	-40	-38	3.4	6.1	6.7
11	6.5	23	-17	-4	18	19	-18	-46	-43	-41	-40	-38	3.7	6.2	6.6
12	6.5	23	-18	-4	18	18	-21	-46	-43	-41	-40	-38	3.7	6.2	6.5
13	6.5	23	-16	-3	18	18	-24	-46	-43	-41	-40	-39	3.6	6.2	6.5
14	6.4	23	-12	0	19	17	-28	-46	-43	-41	-40	-39	3.4	6.1	6.4
15	6.2	25	-6	4	21	17	-31	-45	-43	-41	-40	-38	2.9	5.9	6.2
16	5.9	24	-1	7	21	16	-33	-47	-44	-43	-42	-41	2.4	5.6	6.2
17	5.8	23	7	13	24	20	-25	-46	-44	-42	-41	-40	2.0	5.4	6.4
18	6.2	26	15	22	24	24	-9	-45	-43	-42	-41	-40	2.0	5.8	6.8
19	6.6	29	22	26	27	29	6	-43	-42	-41	-40	-39	2.0	6.2	7.3
20	6.8	30	26	28	28	30	11	-40	-41	-40	-40	-39	2.0	6.4	7.5
21	6.6	29	25	25	28	29	5	-43	-41	-40	-40	-39	2.0	6.1	7.2
22	6.0	29	26	25	28	26	-15	-42	-41	-40	-39	-38	2.0	6.1	7.1
23	5.4	28	22	25	28	18	-42	-42	-41	-40	-39	-38	2.0	5.5	6.4
24	4.9	28	22	25	28	6	-44	-42	-41	-40	-39	-38	2.0	5.0	5.9

Figure 4: Example of Method 2 output

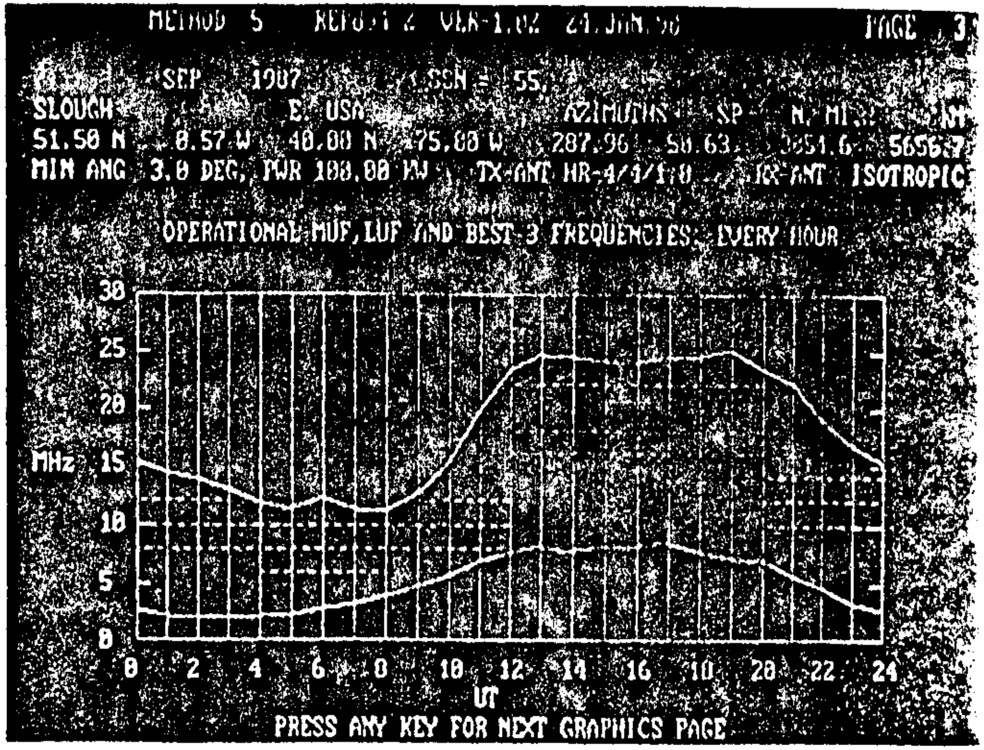

Figure 5: Example of Method 5 output

```
METHOD  6    REP894-2  VER-1.02  24.JAN.90                PAGE   8

          JUN     1986                SSN -  10.
SLOUGH                DOUBBES                AZIMUTHS    SP    N. MI.        KM
51.50 N     0.57 W    50.10 N     4.60 E    111.17  295.18      213.4      395.2
MIN ANG  3.0 DEG, PWR   1.00 KW, XLZ  2.8 DB, XLY -4.2 DB, FTZ DIST  7000. KM
  TX-ANT  ISOTROPIC   TBEAR  0.0              RX-ANT  ISOTROPIC   RBEAR  0.0
    LUF 50      NOISE CATEGORY 1          3000 HZ RX BDWTH       REQ S/N  3 DB
```

UT	MUF											LUF	FOT	OPMUF
13	6.5	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0 FREQ	3.6	6.2	6.5
	1F2	1E	1E	1F2	1F2	1F2	1E	1E	1E	1E	1E MODE			
	56	28	28	56	56	56	28	28	28	28	28 ANGL			
	31	-4	8	27	26	-17	-40	-38	-36	-35	-35 DBU			
	23	-16	-3	18	18	-24	-46	-43	-41	-40	-39 S/N			
	.93	.07	.26	.87	.88	.01	.01	.01	.01	.01	.01 FS/N			
14	6.4	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0 FREQ	3.4	6.1	6.4
	1F2	1E	1E	1F2	1F2	1F2	1E	1E	1E	1E	1E MODE			
	56	28	28	56	56	56	28	28	28	28	28 ANGL			
	32	0	11	29	26	-21	-39	-37	-36	-35	-35 DBU			
	23	-12	0	19	17	-28	-46	-43	-41	-40	-39 S/N			
	.93	.12	.36	.88	.87	.01	.01	.01	.01	.01	.01 FS/N			
15	6.2	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0 FREQ	2.9	5.9	6.2
	1F2	1E	1E	1F2	1F2	1F2	1E	1E	1E	1E	1E MODE			
	56	28	28	56	56	56	28	28	28	28	28 ANGL			
	33	6	15	30	26	-23	-38	-37	-36	-35	-34 DBU			
	25	-6	4	21	17	-31	-45	-43	-41	-40	-38 S/N			
	.95	.22	.54	.90	.87	.01	.01	.01	.01	.01	.01 FS/N			
16	5.9	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0 FREQ	2.4	5.6	6.2
	1F2	1E	1E	1F2	1F2	1F2	1E	1E	1E	1E	1E MODE			
	56	28	28	56	56	56	28	28	28	28	28 ANGL			
	33	12	18	30	25	-25	-40	-38	-38	-37	-37 DBU			
	24	-1	7	21	16	-33	-47	-44	-43	-42	-41 S/N			
	.94	.35	.64	.91	.86	.01	.01	.01	.01	.01	.01 FS/N			
17	5.8	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0 FREQ	2.0	5.4	6.4
	1F2	1E	1E	1F2	1F2	1F2	1E	1E	1E	1E	1E MODE			
	55	28	28	55	55	55	28	28	28	28	28 ANGL			
	32	20	24	33	28	-17	-39	-38	-37	-37	-36 DBU			
	23	7	13	24	20	-25	-46	-44	-42	-41	-40 S/N			
	.94	.64	.78	.94	.91	.01	.01	.01	.01	.01	.01 FS/N			
18	6.2	2.0	3.0	5.0	7.0	9.5	12.0	15.0	18.0	21.5	26.0 FREQ	2.0	5.8	6.8
	1F2	1E	1E	1F2	1F2	1F2	1E	1E	1E	1E	1E MODE			
	55	28	28	55	55	55	28	28	28	28	28 ANGL			
	35	28	33	33	33	-1	-38	-37	-37	-36	-36 DBU			
	26	15	22	24	24	-9	-45	-43	-42	-41	-40 S/N			
	.97	.81	.90	.95	.96	.05	.01	.01	.01	.01	.01 FS/N			

Figure 6 : Example of Method 6 output


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          OCT     1990                SSN - 140.
SYDNEY 10 MV LP      LONDON                  AZIMUTHS     LP    N. MI.       KM
33.83 S   151.17 E   51.00 N     0.10 W    138.19   241.63    12420.8  23016.3
MIN ANG  3.0 DEG, PWR  10.00 MW, XLZ  2.8 DB, XLY -4.2 DB, FTZ DIST  7000. KM
  TX-ANT MR-2/4/0.8    TBEAR 14.0             RX-ANT  ISOTROPIC   RBEAR  0.0
    LUF 50          -135 NOISE DBU            1 HZ RX BDWTH        REQ S/N 47 DB
```

UT	MUF											LUF	FOT	OPMUF
2	16.9	5.0	7.0	10.0	14.0	18.0	22.0	26.0	0.0	0.0	0.0 FREQ	14.1	17.3	20.3
	-	-	-	-	-	-	-	-	-	-	- MODE			
	-	-	-	-	-	-	-	-	-	-	- ANGL			
	29	-138	-53	-1	23	30	28	22	-999	-999	-999 DBU			
	53	-118	-32	22	47	54	53	47	0	0	0 S/N			
	.76	.01	.01	.01	.48	.79	.76	.50	.00	.00	.00 FS/N			
4	16.1	5.0	7.0	10.0	14.0	18.0	22.0	26.0	0.0	0.0	0.0 FREQ	11.4	16.4	19.3
	-	-	-	-	-	-	-	-	-	-	- MODE			
	-	-	-	-	-	-	-	-	-	-	- ANGL			
	33	-82	-20	16	32	33	28	19	-999	-999	-999 DBU			
	57	-62	1	39	55	57	53	45	0	0	0 S/N			
	.87	.01	.01	.08	.85	.87	.77	.34	.00	.00	.00 FS/N			
6	13.2	5.0	7.0	10.0	14.0	18.0	22.0	26.0	0.0	0.0	0.0 FREQ	8.0	13.4	15.8
	-	-	-	-	-	-	-	-	-	-	- MODE			
	-	-	-	-	-	-	-	-	-	-	- ANGL			
	38	-15	17	35	37	31	20	5	-999	-999	-999 DBU			
	61	5	38	57	61	56	45	30	0	0	0 S/N			
	.95	.01	.12	.88	.95	.83	.35	.01	.00	.00	.00 FS/N			
8	26.2	5.0	7.0	10.0	14.0	18.0	22.0	26.0	0.0	0.0	0.0 FREQ	4.6	29.0	34.1
	-	-	-	-	-	-	-	-	-	-	- MODE			
	-	-	-	-	-	-	-	-	-	-	- ANGL			
	45	33	48	56	58	55	51	46	-999	-999	-999 DBU			
	71	53	69	78	81	80	76	71	0	0	0 S/N			
	.99	.74	.99	.99	.99	.99	.99	.99	.00	.00	.00 FS/N			
10	24.2	5.0	7.0	10.0	14.0	18.0	22.0	26.0	0.0	0.0	0.0 FREQ	12.3	24.7	29.0
	-	-	-	-	-	-	-	-	-	-	- MODE			
	-	-	-	-	-	-	-	-	-	-	- ANGL			
	38	-120	-41	7	31	39	39	37	-999	-999	-999 DBU			
	64	-100	-20	30	54	63	64	62	0	0	0 S/N			
	.94	.01	.01	.01	.81	.93	.95	.92	.00	.00	.00 FS/N			
12	21.7	5.0	7.0	10.0	14.0	18.0	22.0	26.0	0.0	0.0	0.0 FREQ	19.2	22.2	26.1
	-	-	-	-	-	-	-	-	-	-	- MODE			
	-	-	-	-	-	-	-	-	-	-	- ANGL			
	26	-291	-141	-47	1	20	26	27	-999	-999	-999 DBU			
	51	-271	-120	-25	24	44	51	52	0	0	0 S/N			
	.68	.01	.01	.01	.01	.30	.69	.72	.00	.00	.00 FS/N			

Figure 7 : Further example of Method 6 output

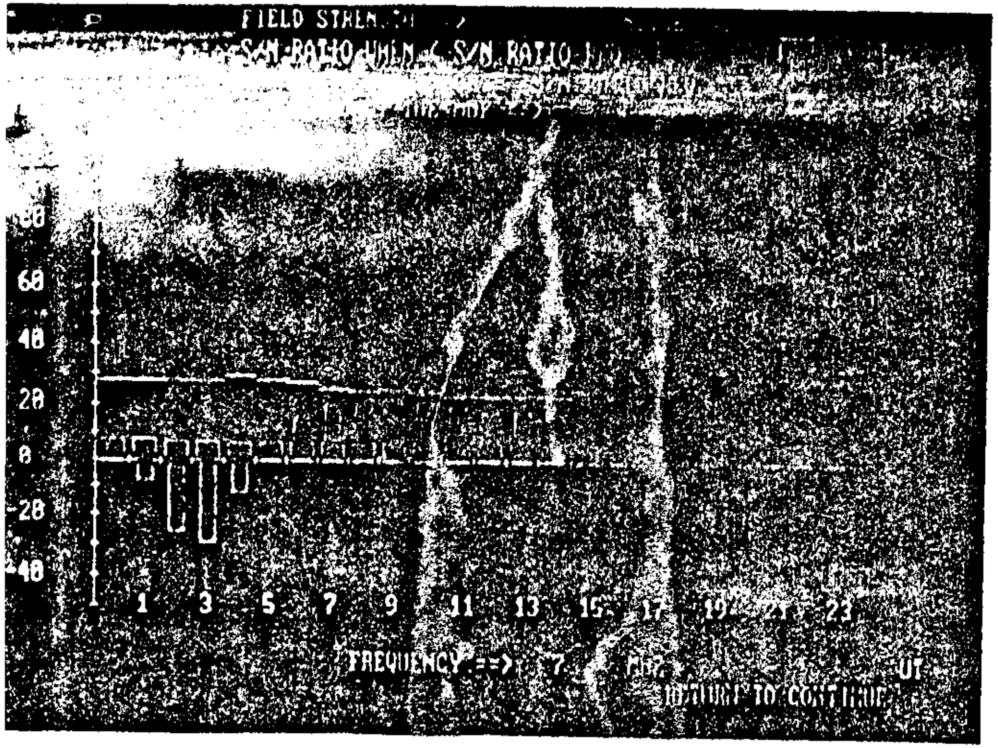

Figure 9 : Example of CNET graphics presentation of field strength, noise power and signal/noise ratio for a selected frequency

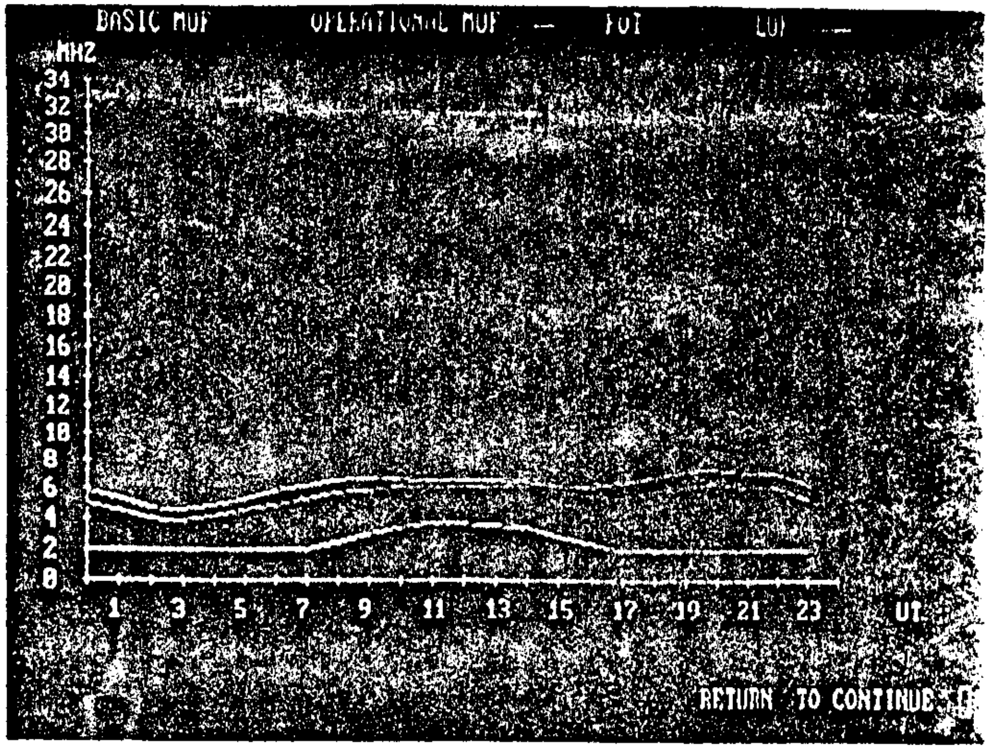

Figure 8 Example of CNET graphics presentation of basic and operational MUF, FOT and LUF